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A Discrete-event Simulation Methodology to Optimize the Number of Beds in Hospital

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Abstract— **In this paper we proposed a discrete event simulation methodology to optimize the number of beds in each unit of inpatient care in hospitals with respect to the bed occupancy rate (percentage of the utility of the bed). Value of the optimal bed occupancy rate is targeted by a Hospital ranged from 50-80%. Simulation method proposed here is used as a solution to the problem in achieving the target bed occupancy rate. This study aims to evaluate the system performance hospitalization services, polyclinics, and emergency room (ER) and gives suggestions optimal number of beds in accordance with the allocation of beds. The data collected is data on the number of patients, the arrival time data ER and clinic patients, data registration time, inspection time data, data on the number of patients on inpatient care units, the data number of beds, average data length of stay (average length of hospitalization), and the data bed occupancy rate (% utility bed). Based on the data collection was conducted early development of simulation models and systems analysis, so that the results of the analysis can be carried out experiments on the proposed allocation model using the bed scenario "what-if". A case study in a hospital owned by Government of Jakarta analyzed with simulation models and the results are validated with the factual data in the field**

Index Terms— **discrete-event simulation, bed occupancy rate, hospital modeling.**

I. INTRODUCTION

Hospital is one of a growing service industry in Indonesia, and health services is one important factor in people's lives, which can increase the competition that leads to fulfillment of the demands of patient needs both in quantity and quality. That's very important to be done by the Hospital to improve services to the community. Department of Health noted that public expenditure for health services each year increased by about 7%, while total spending each year close to 9% of Gross Domestic Bruto (GDP) of Indonesia. The result of the analysis of health expenditure shows that about 7% of the money went to the Hospital, Community Health Center, Health Clinic and Alternative Medicine. According to Health Department records, the total hospital expenditure per year doubled from the previous year.

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From the managerial perspective, there are two crucial issues in making policies related to health services and the budget, namely the understanding of the inefficiency in Hospital and how to improve efficiency. One attempt to improve the operational efficiency of a hospital is to control operational expenses and provide a satisfactory service to the community. In addition, another problem often encountered by hospitals and patients are:

- longer waiting time for patients to enroll in the Hospital
- the bottleneck in a particular service unit that can reduce access to health services to the community
- time to wait longer for certain patients
- occurs one placement for a patient to a higher cost (when a patient who requires a level of care placed on the lower level of high maintenance) or low quality (when patients who require higher levels of care in place at a lower level)
- high operational costs due to inefficiencies Hospital.

Hospitals can be viewed as a system where the management is dynamic and the flow of patients who happened often are complex (complexity), uncertain (uncertainty), and fickle (Variability). To evaluate the performance of a hospital that has such properties is required to service modeling done by the Hospital involving a high level of accuracy associated with the characteristics of the patient's arrival at the hospital and the use of various statistical distributions to accommodate the variability that occurs. This should be realized by the stakeholders (shareholders) Hospital to support the planning and resource management hospital.

The purpose of this paper is to propose a methodology and its application illustrated with a case study in a government owned hospital in Jakarta. In this case study we can identify the performance of system in term of inpatient care units, polyclinics, and the emergency; and we also provide some suggestions the optimal number of beds in accordance with the allocation of the bed. This paper arranged in the following order. Section 2 provides a literature review on the evaluation of hospital services. In Section 3 the proposed methodology described in this paper. In Part 4 of the case study at a government owned hospital in Jakarta. Finally in Section 5, described the conclusions and suggestions for the next study.

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II. LITERATURE REVIEW

Modeling process of a hospital service system involving all operational activities in all service units, such as the interaction between service units which occur by considering the nature of system variability. This modeling process involves stakeholders in the allocation of overall resources to collect data and perform validation. In addition, during the process of modeling the system of hospital services required a thorough understanding of the model, which involves some supporting theory as the theory of queues, interactive modeling approach and the use of discrete-event simulation. Here are summarized some results of research on health services in hospitals that have been done by some previous researchers.

Preater (2002) presents a bibliography of over 150 papers on the application of queuing theory in health care and medicine. He classifies the papers are based on the scope of applications in five categories, namely Appointments, Departments, Ambulances, Compartmental Modeling, and Miscellaneous. They divide the number of articles into two parts, the article assesses the patient flow and resource allocation. A survey on the application of the dynamic flow method performed by Dangerfield (1999). Furthermore, a database of articles related to the application of Operations Research (OR) in the health services available in Churilov and Carter (2004).

Although much literature on the application of queuing theory in health services already available, but none of these papers use queuing network model and discrete event simulation for systems with more than one or two units. Queue has an advantage in producing a simpler model using relatively little data if it involves the nature of randomness. Gorunescu et al. (2002) uses a queuing model for bed allocation plan in a department of geriatric patients. They use a model M / M / c / K to demonstrate how changes in patient enrollment rates, and length of stay of patients in bed allocation influence bed occupancy rate in a unit of service. The results show that the discharge of the bed between 10-15% is required to maintain the efficiency of service to patients. Previously, Ridge et al. (1998) uses a model M / M / c with priority given to emergency patients and patients specifically to analyze the six-bed Intensive Care Unit (ICU). They calculate the length of time patients wait for emergency and special patient in the queue. Queuing model was used for the purpose of validating a simulation model. Kim et al. (1999) also uses a queuing model M / M / c to analyze the capacity of 14 ICU beds. They have four types of patients in his model by using three different ways to calculate the average service time for queue model.

Cohran and Bharti (2006) uses a stochastic methodology to balance utility bed Percentage of patients by performing the allocation of the bed using the scenario of "what-if" simulations at a hospital in the Southwestern USA. While Elbeyli and Krishnan (2006) uses simulation to analyze the occurrence of bottlenecks (piling), the arrival of patients and aim to reduce patient waiting time in emergency rooms, by adding the number of beds in the ward using the scenario of "what-if" simulations.

Discrete event simulation has been used in various applications. Mahachek and Knabe (1984) analyzed the flow of patients in the obstetrical department and gynaecologikal, to evaluate the two planning clinic. The results prove that the second surgery clinic is not feasible. Furthermore, Dumas (1984) used a computer simulation model to solve the problem of allocation of beds in a hospital bed, taking into account the type and sex of the patient. He relocated in a hospital bed with a view to minimizing the error placement of the patient. In a model of Dumas, a patient is placed in some other unit (which is called by the wrong placement), if a bed is required a patient was not available. Bagust et al. (1999) identify the implications of the emergency patient registration request which fluctuates and is unpredictable in the management of bed capacities in hospitals

III. DISCRETE-EVENT SIMULATION METHODOLOGY

A methodology, called discrete event simulation, it is proposed to evaluate and optimize the optimal number of beds in hospitals. The main objective of this methodology is to define a stage of the procedure to optimize the number of beds in hospitals using discrete event simulation model. The proposed methodology is presented in Figure 1-2. Using this methodology will be explained later in this paper using a case study.

Simulation is an operational imitation of a real process or system is statistically in a particular period to generate stochastic behavior. Modeling discrete event simulation is a system whereby the system state variables change only at certain times (discrete), such as arrival and departure from the queue. Measuring the performance of discrete event simulation are estimated using statistical methods, not using the analytical method. Discrete event simulation is more flexible in terms of modeling assumptions, but using more data. After the simulation model was developed and validated, then a discrete event simulation model can be used to investigate various what-if scenarios about the real world system.

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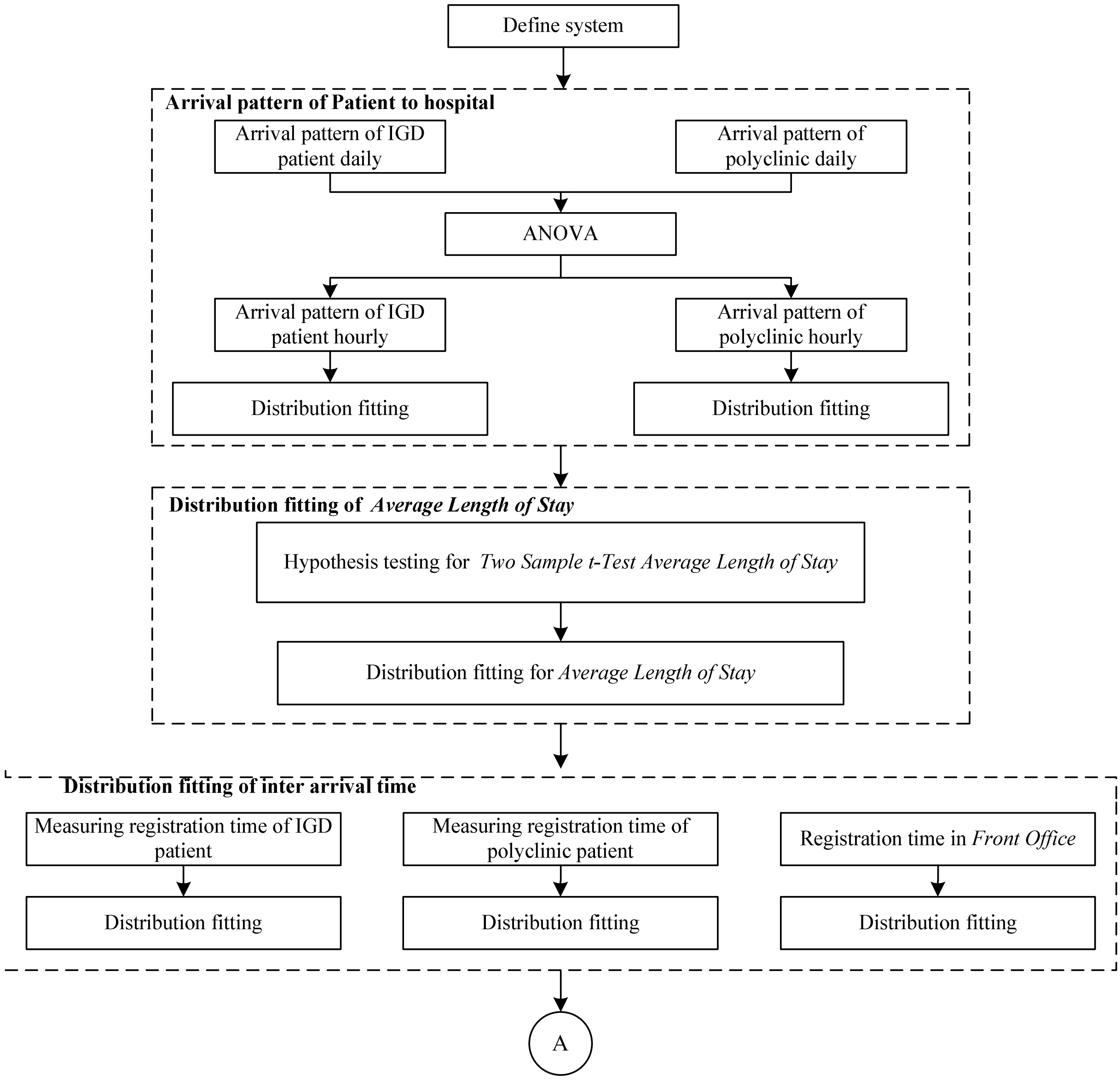

Figure 1 Methodology of discrete event simulation to optimize the number of beds in hospital

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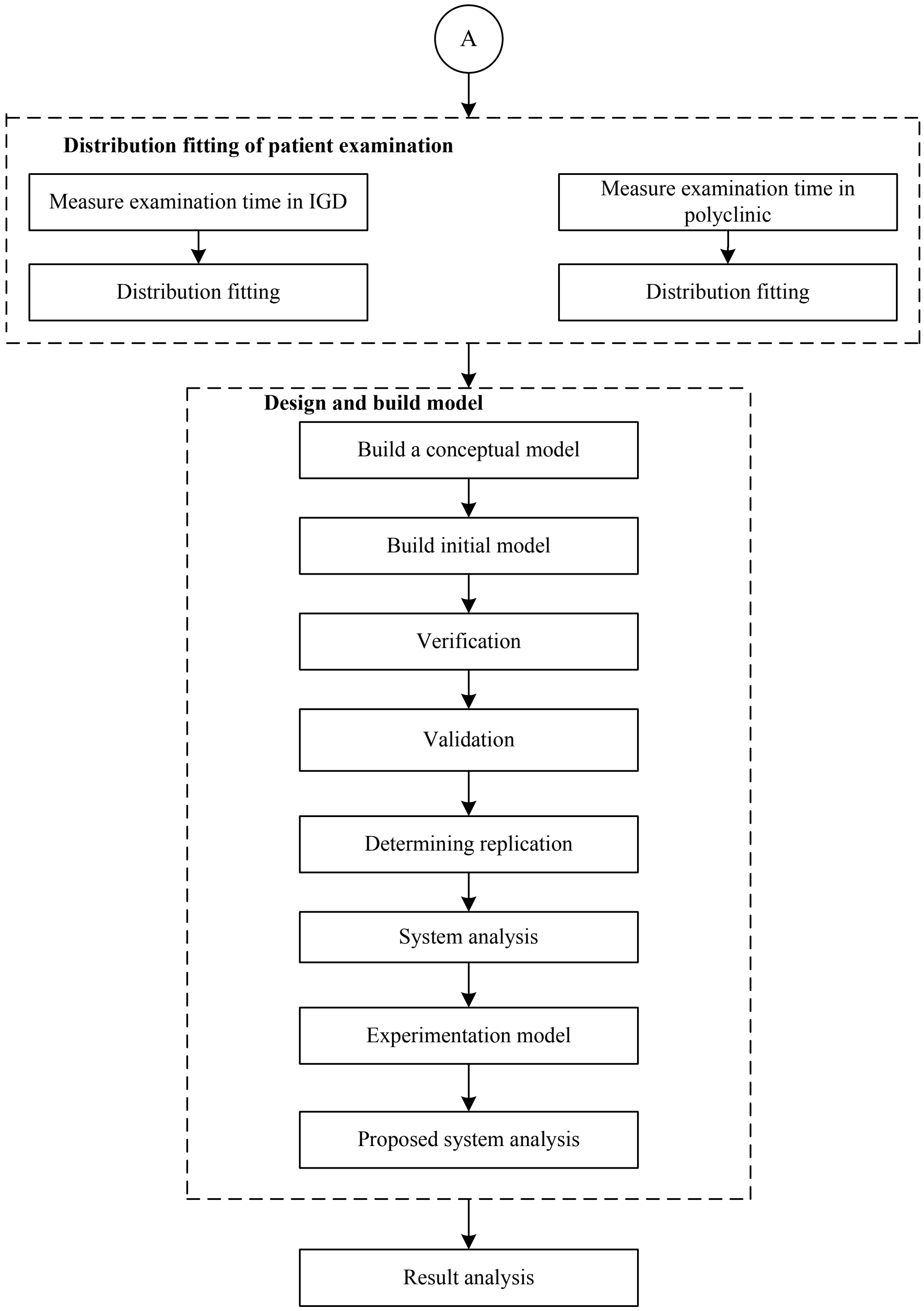

Figure 2 Methodology of discrete event simulation to optimize the number of beds in hospital (*continued*)

IV. CASE STUDY AND RESULTS

A study has been conducted in a hospital to evaluate and optimize the number of bed patients by using the proposed methodology. The research object under study is a hospital owned by local government of Jakarta, which offers various medical services. The system is meant here is a set of important variables that can explain the behavior of real systems at a particular time and has a particular purpose. System to be observed in the hospital consists of 272 beds are distributed on 8 inpatient care units and 2 units of inspection, with the following explanation:

a. Installation of emergency room (ER): The unit in which emergency patients came in and did an early examination before treatment is continued. ER has 18 beds.
b. Clinic: Unit where patient clinic examination prior to further treatment. Polyclinic has 21 beds.
c. Pediatrics (PEDS): Unit of child care to the diagnosis varied, such as internal medicine, surgery, lung and respiratory tract. PEDS care unit has 49 beds.
d. High Care (HC): Intensive room for children, with a higher level of care. HC-care unit has 2 beds.
e. Intensive care unit (ICU): The room in intensive care for adult patients who require higher levels of care to

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the diagnosis varied, for example, is a cancer, respiratory, and other common medications. ICU care units have 2 beds.

f. Cardio Vascular Cardiac care (CVCU): cardiac intensive care room and blood vessels. CVCU care unit consisting of 2 beds.
g. Gynecology (GYN): Space obstetrics and gynecology who provide medical and surgical services. GYN care unit has 45 beds.
h. Space in the disease (PD): This unit provides specialized care for patients who suffer from the disease, such as kidney disorders, diabetes and dengue fever. PD-care unit has 43 beds.
i. Room lung disease (PP): This unit provides specialized care for patients suffering from lung diseases, such as bronchitis. PP room has 36 beds.
j. General surgery Space (BU): This unit serves patients with general surgery needs. BU room has 54 beds.

Care units were grouped into 4 categories, namely intensive care, medical/surgical, general child care, child care and intensive. According to hospital management, the grouping is based on the similarity level of care (level of care), for example, is a unit that is included in the ICU and intensive care CVCU will be grouped into one, because patients who are entered in both units will get the treatment that is higher than other inpatient care units. Similarly, the general care, child care, intensive care and grouped by level of treatment.

Intensive treatment consisted of the ICU and CVCU, ie units that provide care for adult patients with the highest level. Medicine / surgery consisted of GYN, PD, PP, and BU, is a unit that provides general care for adult patients. Child care consists of PEDS, i.e. units that provide general care for children. Intensive child care consists of HC, ie the unit that provides intensive care for children. These groupings will be used for the boundaries pengalokasikan bed.

In addition there are two types of registration that can be passed by the patient, namely through the emergency department and clinic registration.

After the simulation is obtained the average amount of output (the average number of patients) in inpatient care units, polyclinics, and ER, so that in this validation test will use an average value of the number of patients from the initial model simulation results (ie values obtained from the simulation model) and the number of patients in the real system (ie the value obtained from the calculation by the hospitals. In Table 1 are shown the average number of patients the results of simulation and real systems.

In Table 2 are shown the percentage of the utility of simulation results and the actual system, where a percentage value obtained from the simulation model simulation models, while the percentage of the actual system is obtained from the calculation by the hospital.

TABLE 1
COMPARISON OF AVERAGE TOTAL PATIENT BETWEEN SIMULATION AND ACTUAL SYSTEM

Care unit	Simulation	Actual system
Instalasi Gawat Darurat (IGD)	2004,7	2006
Poliklinik	24780	24780
Intensive Care Unit (ICU)	23,4	22
Cardio Vascular Cardiac Care (CVCU)	19,9	20
High Care (HC)	23,2	21
Penyakit Dalam (PD)	424,3	433
Paru-Paru (PP)	268,9	263
Bedah Umum (BU)	246,4	254
Gynecology (GYN)	225,4	220
Pediatrics (PEDS)	317,3	323

TABLE 2
PERSENTAGE UTILITY OF EACH BED

Care unit	Simulation	Actual system
Intensive Care Unit (ICU)	58,25 %	54 %
Cardio Vaskuler Cardiac Care (CVCU)	55,38 %	56 %
High Care (HC)	65,70 %	58 %
Penyakit Dalam (PD)	99,22 %	98 %
Paru-Paru (PP)	83,63 %	82 %
Bedah Umum (BU)	37,60 %	36 %
Gynecology (GYN)	39,02 %	38 %
Pediatrics (PEDS)	70,16 %	73 %

V. CONCLUSIONS AND RECOMMENDATIONS

In this paper, we proposed a discrete event simulation methodology for evaluating and optimizing the number of patient bed hospital. The purpose of this methodology is to balance the utilization of patient beds with a view to reducing patient waiting time. This methodology is applied at a hospital owned by the Government of DKI Jakarta. The proposed methodology also involves stakeholders in the process design and modeling system. The hospital staff at various levels to help in gathering data, verifying the model, validating models, and participated in designing the scenario proposed improvements in hospital services system. For subsequent studies, this methodology could be improved in the following manner:

a. simulation models consider the number of patients who are not accommodated in the service unit
b. Model simulations involving the scheduling of staff and costs
c. Model simulations using the classification of patients according to the wishes of patients, including the application of the FIFO rule (first in first out)
d. simulation models can be integrated with hospital databases to enable a decision can be taken quickly

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